K&C Forest Theme:
Quantitative Height Retrievals and Calibrated Interferometric Coherence

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Need for a Calibrated Coherence Signature

The observed correlation is modeled as the combination of a variety of sources

$$\gamma_{obs} = \gamma_{vol}\gamma_{SNR}\gamma_{geom}\gamma_{temporal}$$

To quantitatively extract the vegetation signature, it is necessary to calibrate the observed coherence

$$\gamma_{vol} = \frac{\gamma_{obs}}{\gamma_{SNR}\gamma_{geom}\gamma_{temp}} = f(h_v)$$

Then …

$$h_v = f^{-1}(\gamma_{vol})$$

The estimation of the error sources is a statistical process

A Temporal Decorrelation Study

- Temporal and volumetric effects on interferometric correlation are hard to separate.

$$\gamma_{temporal}\gamma_{vol} = \frac{\gamma_{obs}}{\gamma_{SNR}\gamma_{geom}}$$

- Baseline length effects overall sensitivity to volumetric effects

$$k_z = \frac{4\pi \mathrm{B}_{\perp}}{\lambda r \sin\theta}$$

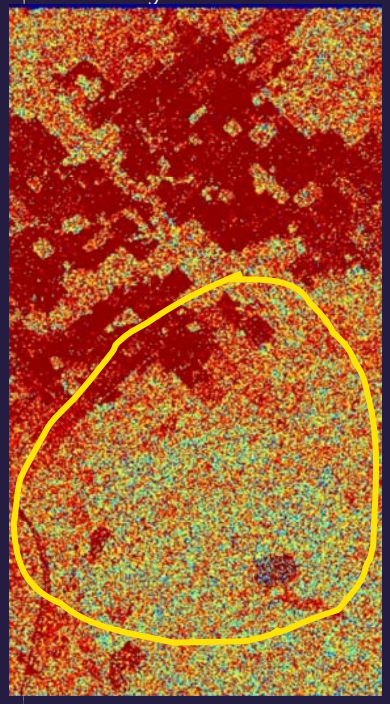
- With knowledge of the baseline and seting a limit for maximum vegetation height, temporal effects can be estimated

$$\gamma_{vol} \le 1 - \frac{h_v^2 k_z^2}{24} \le \mathrm{sinc}\left(k_z h_v / 2\right)$$

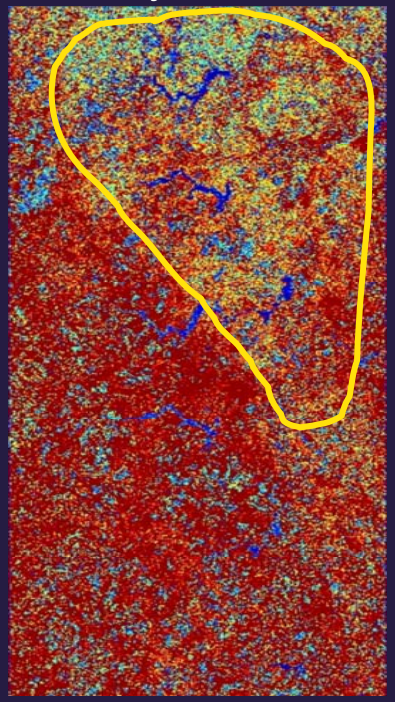
Temporal Decorrelation

- Occurs when the observed electric field changes between passes of the interferometer.
- Single-pass interferometry does not experience temporal decorrelation
- Its magnitude is dependent on target type and weather phenomena, and therefore is difficult to remove as an error source
- Has the effect of causing an overestimation of vegetation heights.

SIR-C, Raco, Michigan
One-day

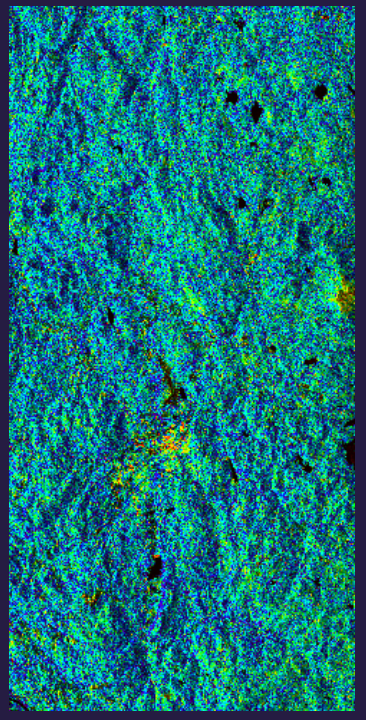


SIR-C, Duke Forest
One-day

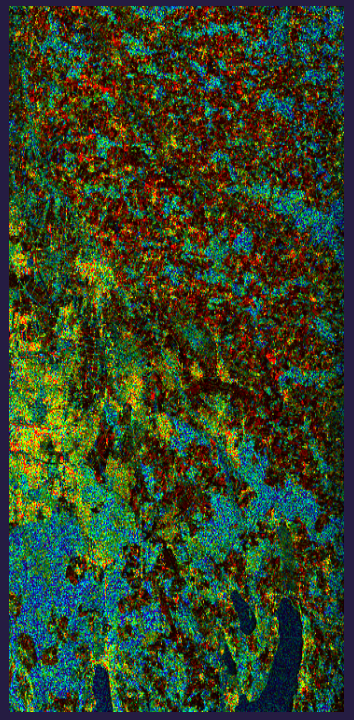


SIR-C, Russia
Two-day

PALSAR, Harvard
Forest, 92 days



PALSAR, Germany
46 days



The Harvard Forest as a Test Site

- The need for a quantiative method for estimating carbon stocks and biomass continues
- The Harvard Forest in Western Massachusetts is one K&C test site being used to develop scalable algroithms that can be applied world-side
- The following is an illustration of the detailed analysis

Introduction

1200 ha in Western Massachusetts, New England Upland Region (200 - 400 m elevation), mean precipitation of 110 cm/year. Transition Hardwoods, White Pine and Hemlocks.

Dominant Species

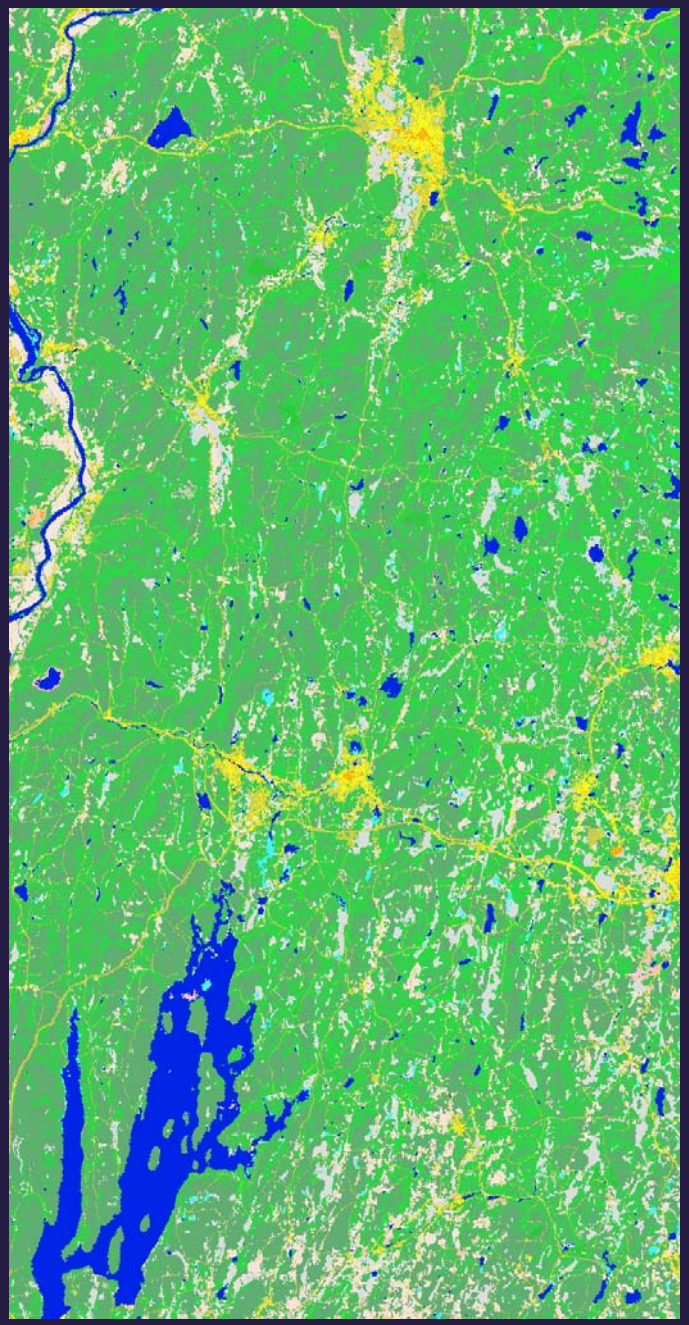
- Red Oak, Red Maple, White Pine, Eastern Hemlock

Secondary Species

- White and Black Oak, Sugar Maple

- Region was heavily forested in early 20th century.
- Donated in 1907 to Harvard University to study sustainable forestry.
- In the 21st century, it has been heavily imaged by ALOS/PALSAR

Classification



A landcover classification (NLCD 2001) is used to perform post-analysis, and to understand the impact of landcover type.

NLCD Classes

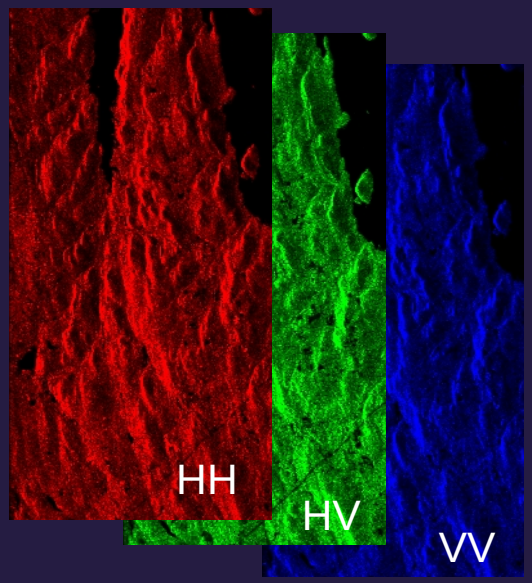
- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial & Transport.
- Bare Rock/Sand
- Quarry/Strip Mine
- Transitional Barren
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Grass/Herbaceous
- Pasture/Hay
- Row Crops
- Small Grains
- Other Grasses
- Woody Wetlands
- Herbacious Wetlands

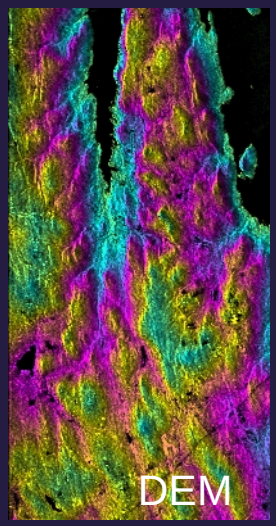
A Variety of Perpendicular Baselines

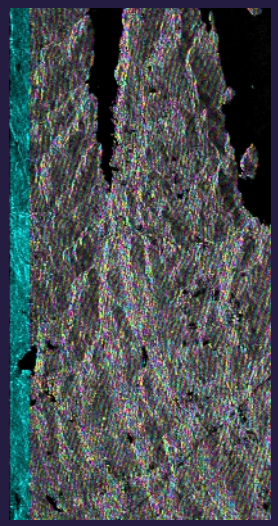
	20060702	20060827	20061012	20061127	20070112	20070414	20070530	20071015	20071130	
	PLR	4270	3800	4510	2440	5150	4580	6170	6220	20060702
		PLR	470	240	1830	890	310	1900	1950	20060827
			PLR	710	1360	1350	780	2370	2420	20061012
				PLR	2070	650	70	1660	1710	20061127
20070105	FBS				PLR	2720	2140	3730	3780	20070112
20070708	2690	FBD				PLR	570	1020	1070	20070414
20070823	2670	80	FBD				PLR	1590	1640	20070530
20071008	3030	345	270	FBS				PLR	50	20071015
20080108	3600	910	830	570	FBS				PLR	20071130
	20070105	20070708	20070823	20071008	20080108					

Above are shown ALOS perpendicular baselines (in meters) for all possible interferometric pairs for a variety of observing modes

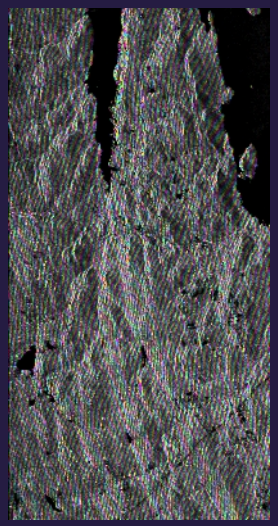
The Processing Chain



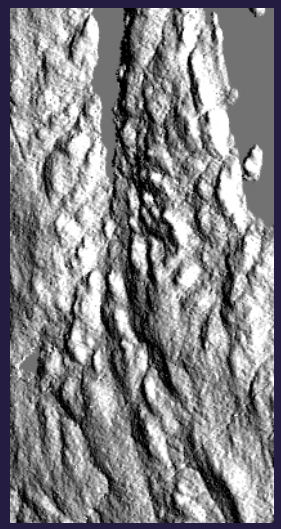




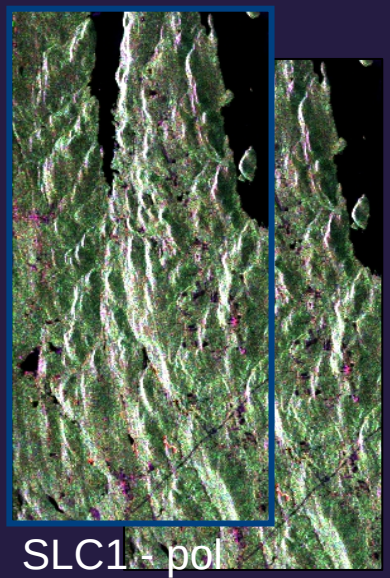
interferogram



simulated interferogram

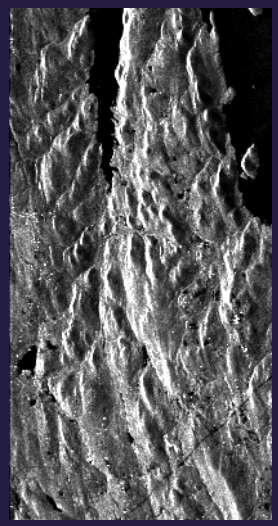


surface area correction



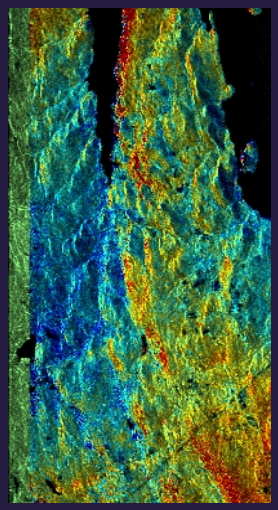
SLC1 - pol

SLC2 - pol

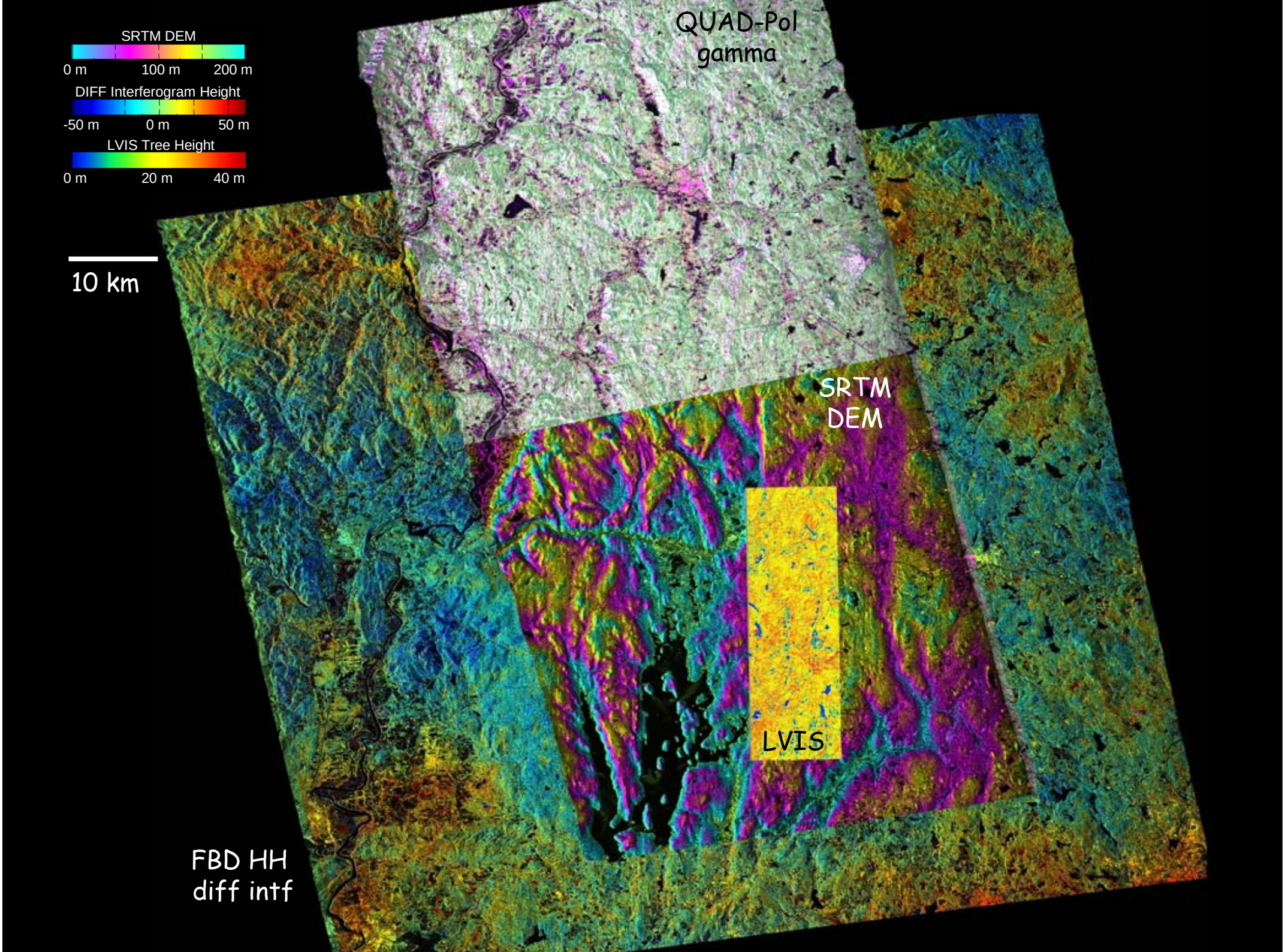


simulated rcs

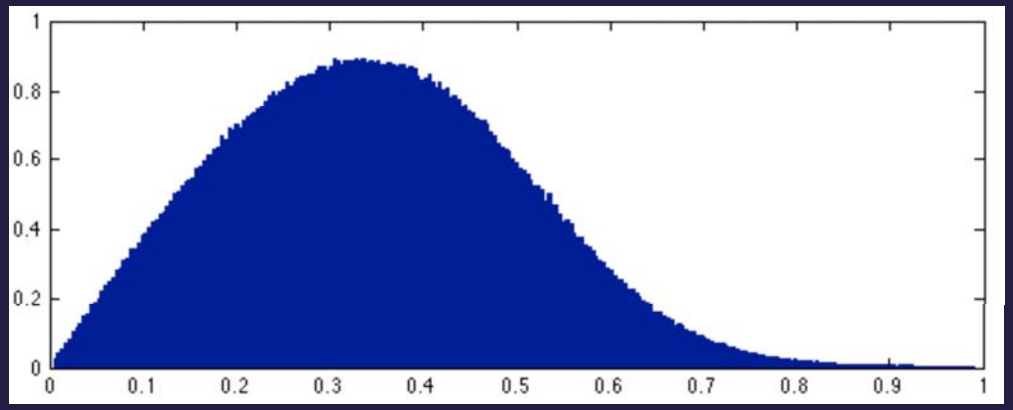
NRCS1 - pol



differential Interferogram


SRTM DEM
0 m
100 m
200 m
DIFF Interferogram Height
-50 m
0 m
50 m
LVIS Tree Height
0 m
20 m
40 m
10 km
QUAD-Pol
gamma
SRTM
DEM
LVIS
FBD HH
diff intf

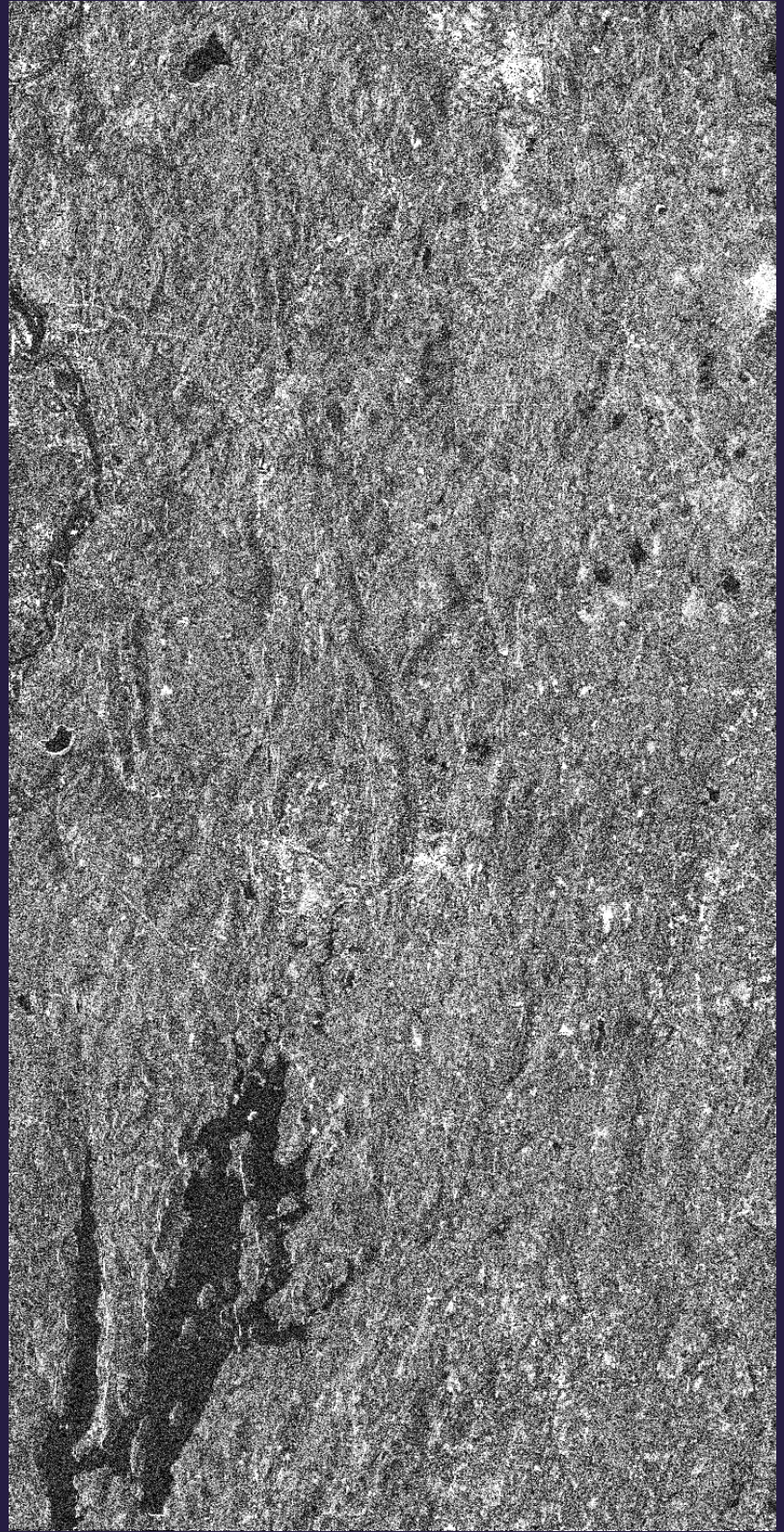
Correlation (uncorrected)



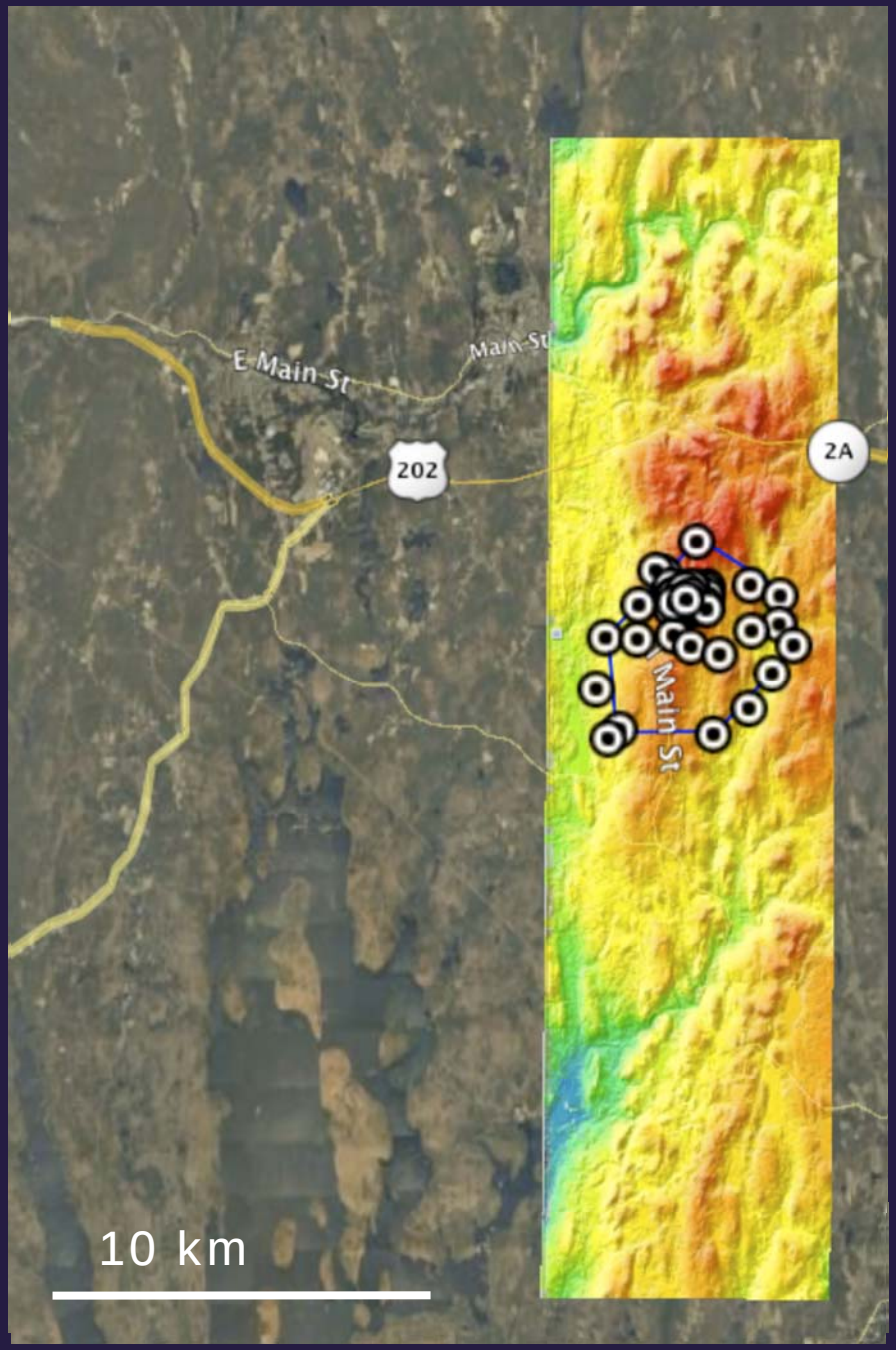
correlation

As reported by many, a 46-day repeat period cuases problems in terms of using the interferometric coherence for InSAR and PolInSAR for quantitative estimation of vegetation characteristics.

Use of coherence may still be suitable for forest/non-forest classification.

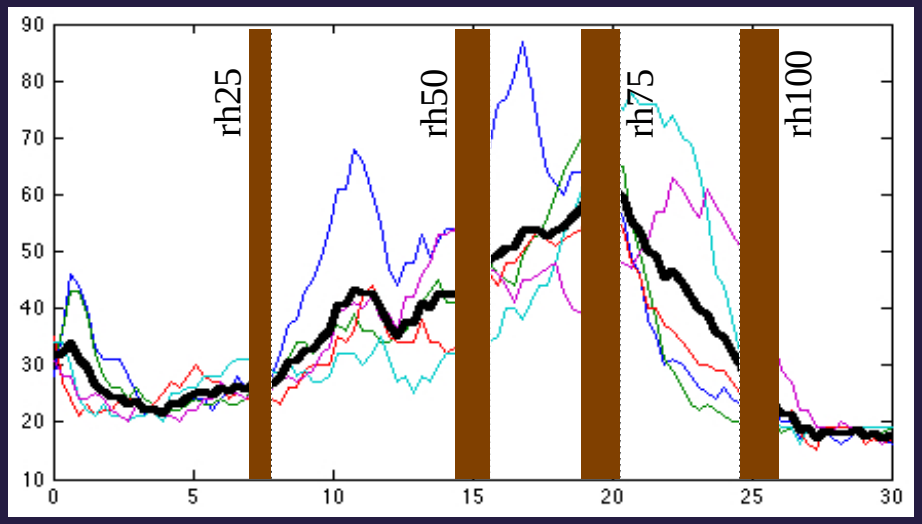


Lidar and Ground Validation Sites

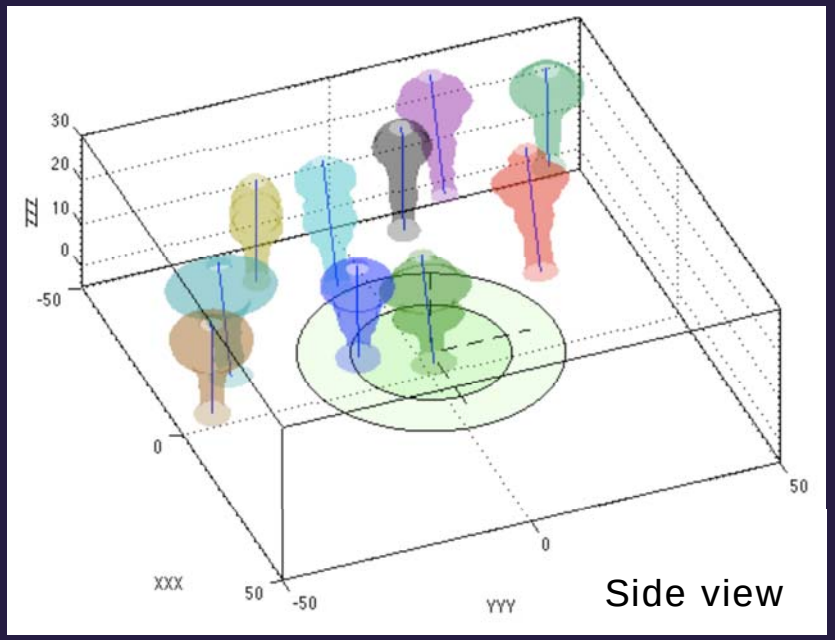


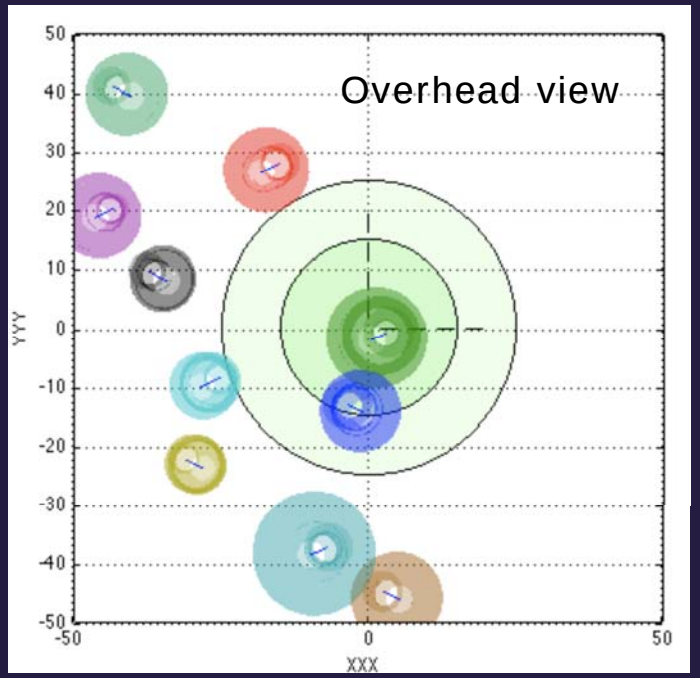
- Local region of the Harvard Forest (fully covered by ALOS observations).
- LVIS full waveform LiDAR data collected in July of 2004.
- Harvard Univerisity has 44 biomass sites (700 m^2), 34 of which are covered by the LVIS observations.

Working With LiDAR Data

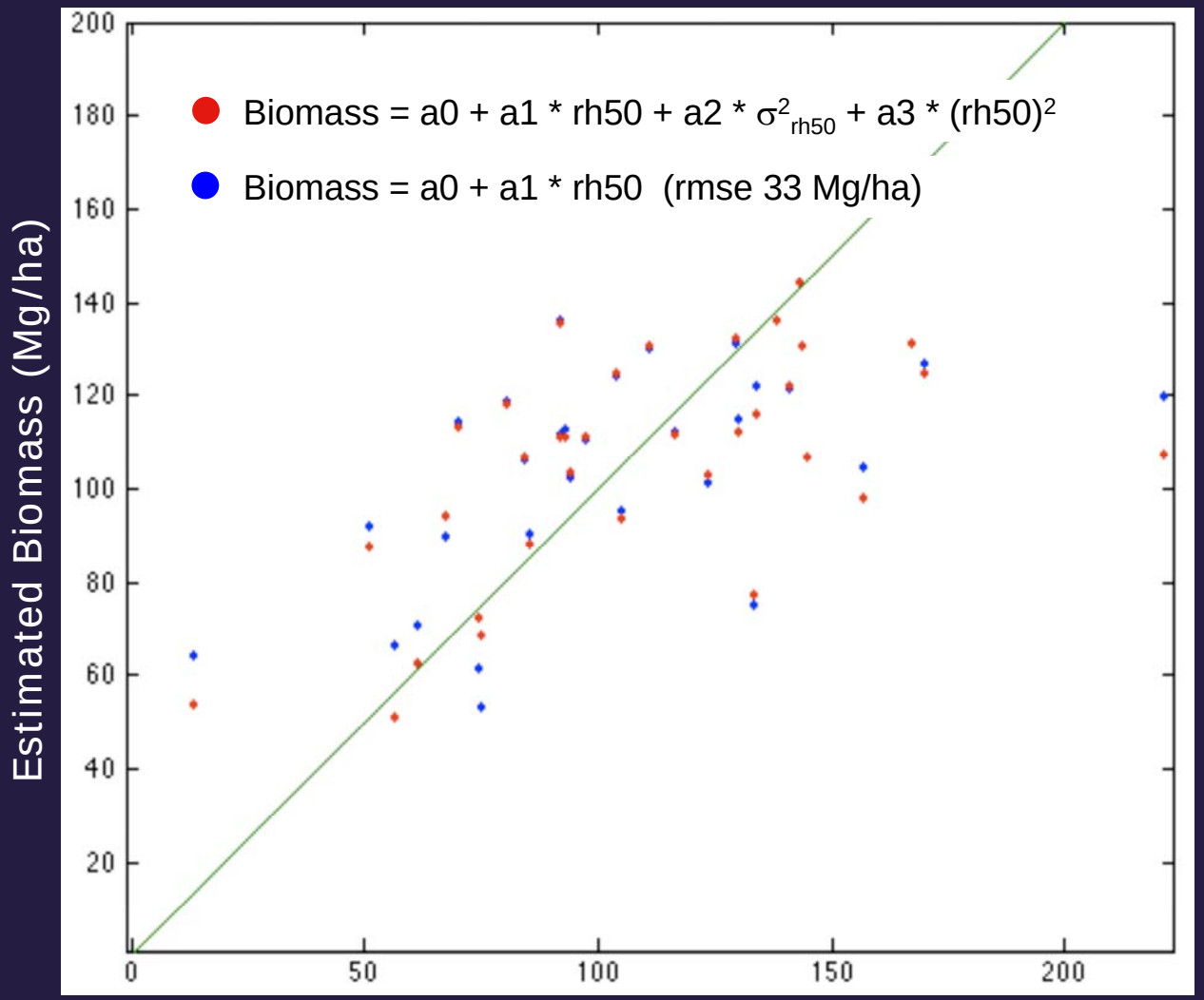


Google Earth





Biomass to LiDAR Relationships



Other Variables

rh100

rh75

rh50

rh25

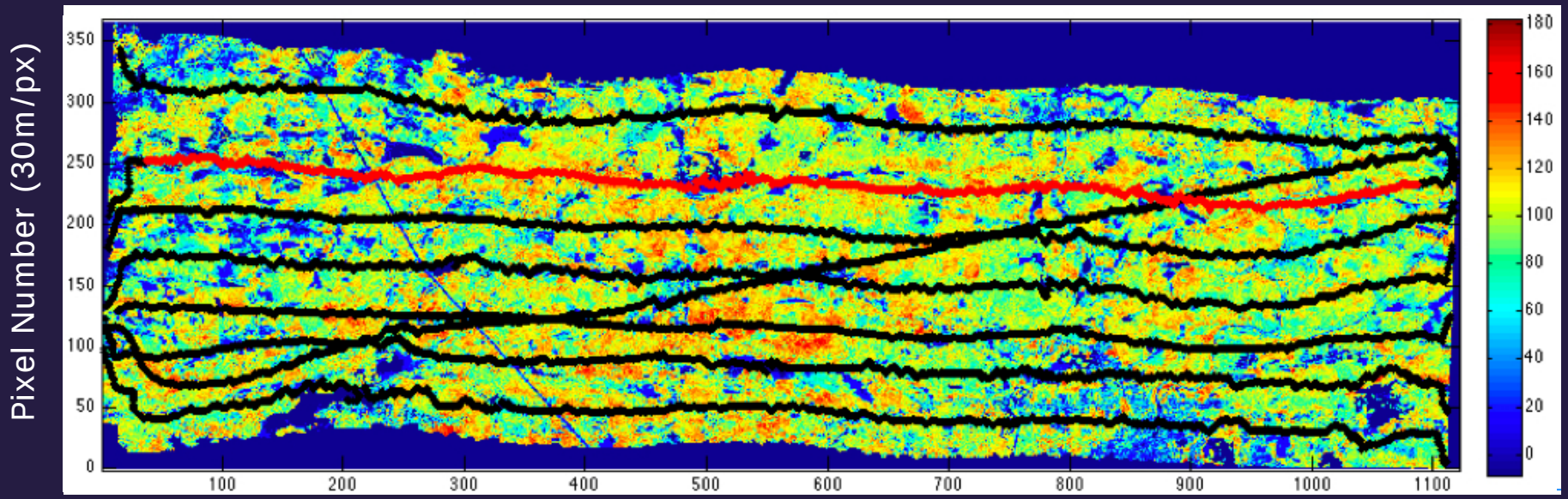
$(rh50)^2$

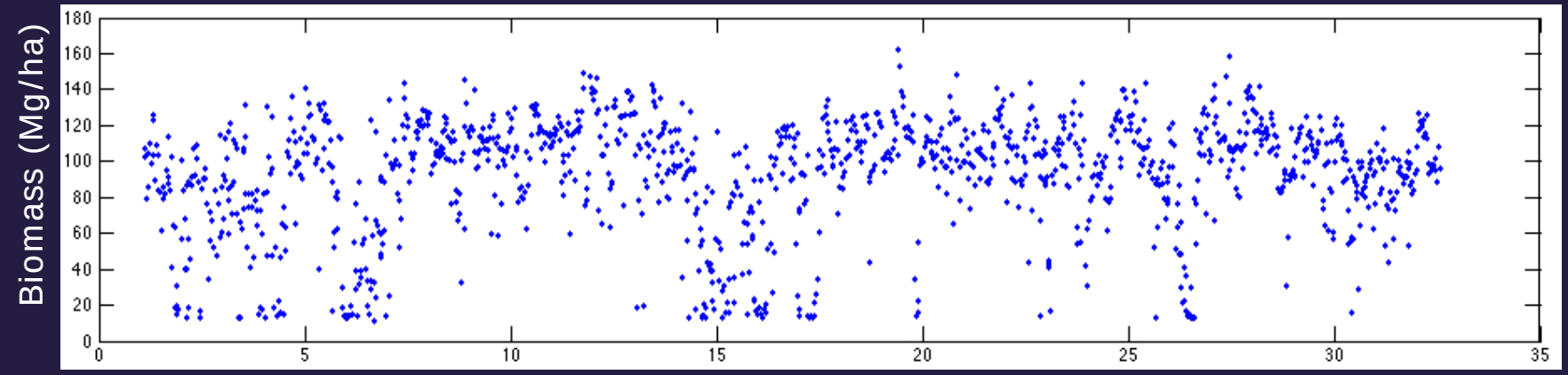
$(rh100)^2$

σ^2_{rh50}

σ^2_{rh100}

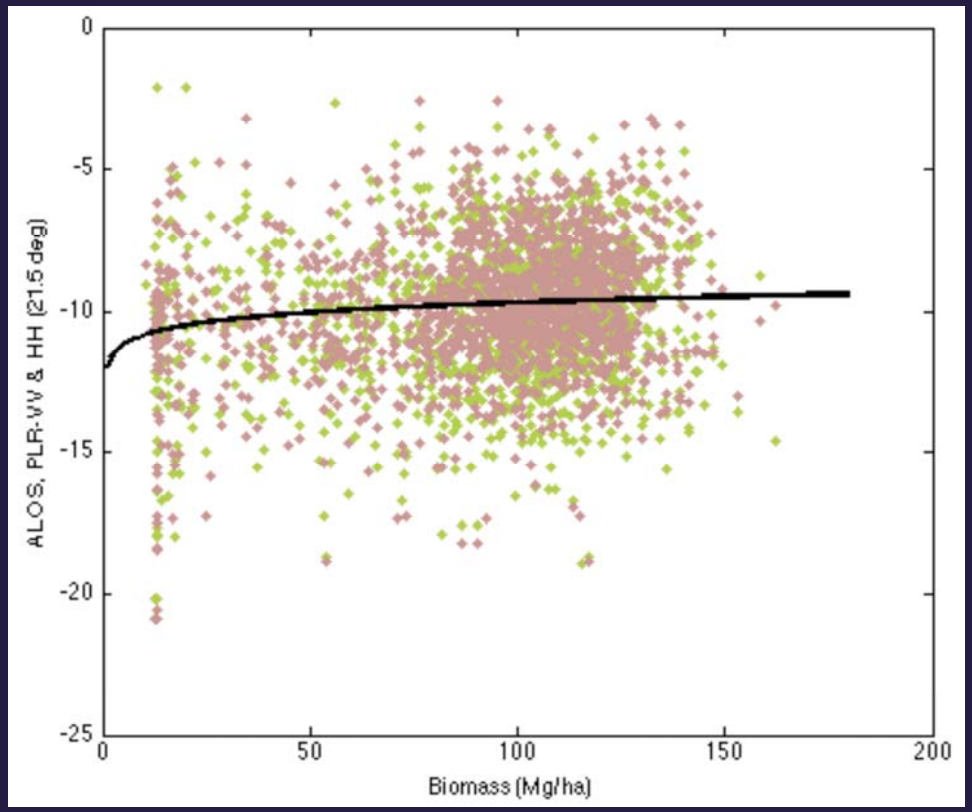
A Biomass Map of the Harvard Forest





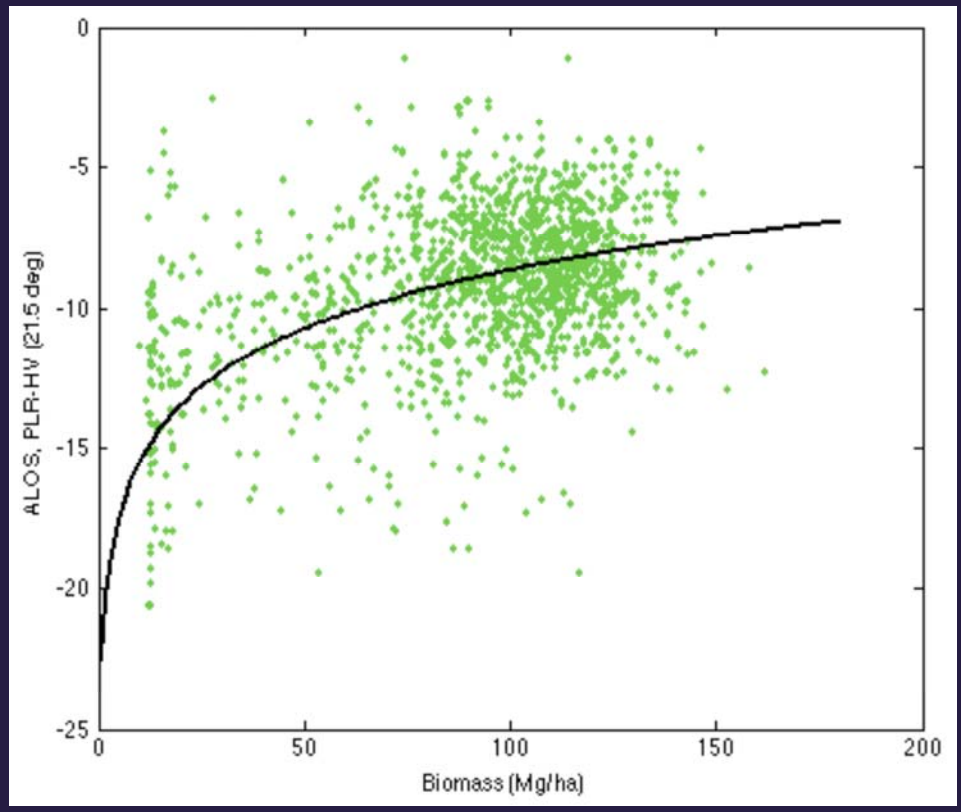
Biomass Estimation using Radar RCS

LHH & LVV



σ^{o}_{hh} = -12 + 0.5 ln AGB

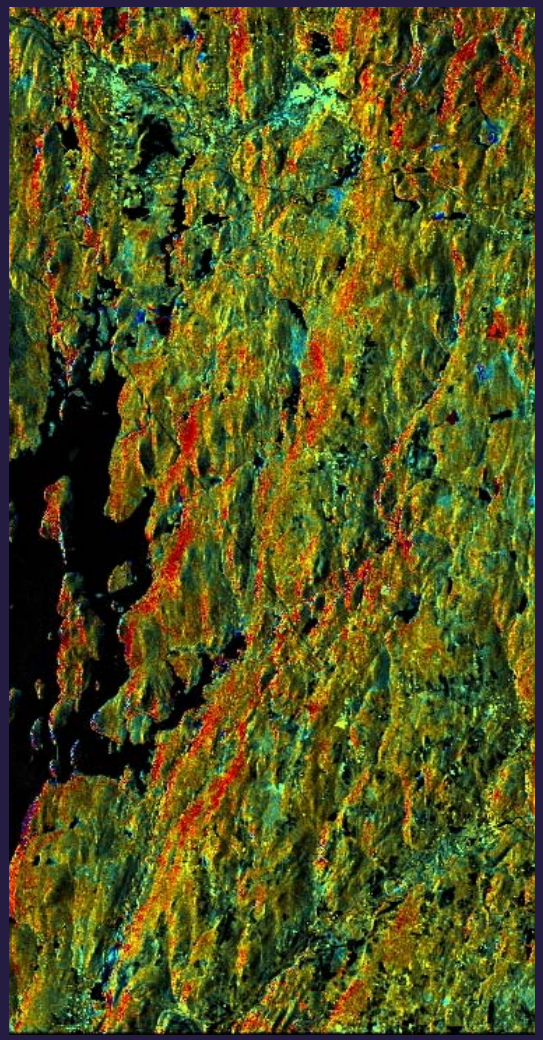
LHV



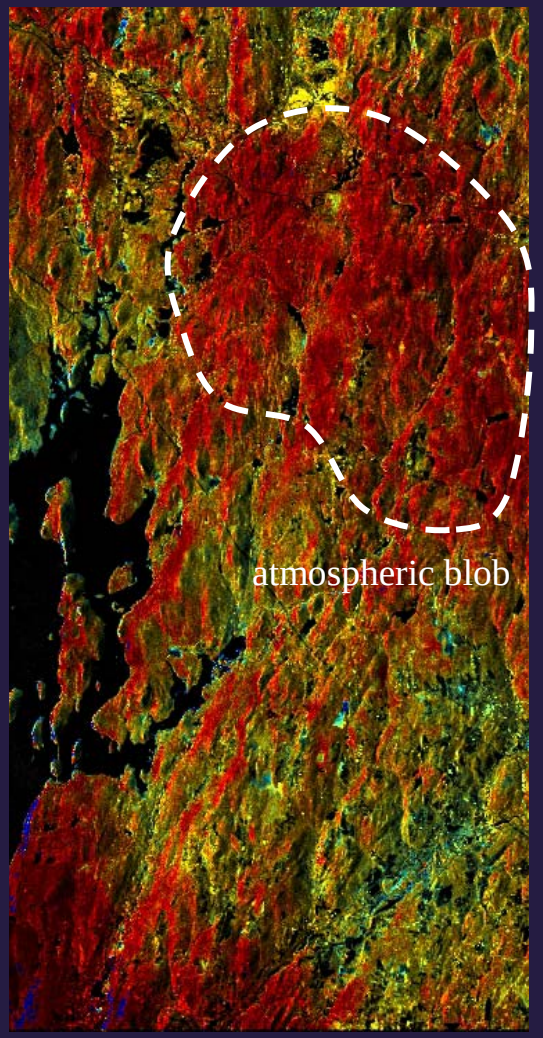
σ^{o}_{hv} = -22.5 + 3.0 ln AGB

Differential Inerferometry?

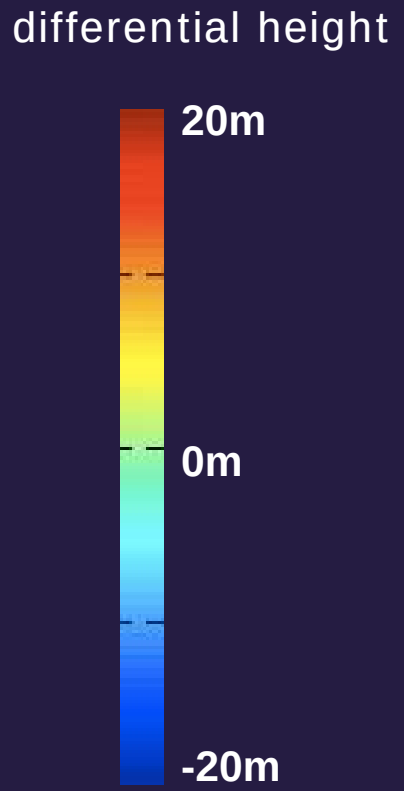
- A C-band DEM and PALSAR interferometric pairs could, in principal, be used to measure differential penetration
- Initial results show that the signature is dominated by atmospheric effects



PALSAR, PLR HH
11/06 - 12/06 Diff. Hgt.



PALSAR, PLR HH
12/06 - 4/07 Diff. Hgt.



Conclusions

- Temporal Decorrelation is prevelant in all interferometric data, even one-day repeat pass interferometry
- Significant ALOS, dual-pol and quad-pol observations exist over the Harvard Forest
- Because of temporal decorrelation, we have been looking so far only at the radar cross-section
- Full waveform data from LVIS was used to generate a biomass map.
- Fully polarimetric data shows a loose relationship to biomass for the cross-pol. Nothing for the co-pol. Likely due to the steep incidence angle.
- Next will look at polarimetric decompositions and at the FBS/FBD data and to extend the region of study

Other Backscatter Relationships